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SOME ASPECTS ON THE BIOLOGY
OF
DEROCERAS PANORMITANUM and DEROCERAS RETICULATUM
WITH
SPECIAL EMPHASIS ON EFFECTS CAUSED
BY
SOME COMMON AGRICULTURAL CHEMICALS

A Thesis presented in partial fulfilment of the requirements
for the degree of Masterate of Science in Zoology at
MASSEY UNIVERSITY

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Year.....1980.....



PLATE I DEROCERAS RETICULATUM (MULLER, 1774.)

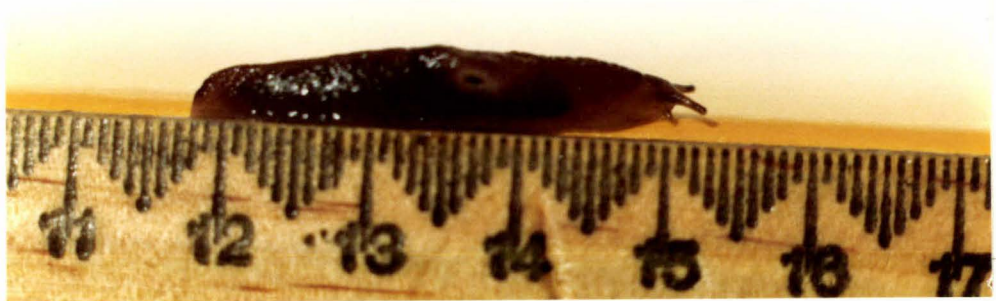


PLATE II DEROCERAS PANORMITANUM (LESSONA & POLLONERA, 1882.)

- ABSTRACT -

Two species of slugs Deroceras panormitanum (Lessona & Pollonera, 1882), and Deroceras reticulatum (Muller, 1774), were chosen as a subject for investigation. In part 'A' the fecundity and longevity of D. panormitanum was observed at four different locations, three at constant temperatures, and the fourth in Shade-house, which was the control site. A seasonal effect was evident in Shade-house, more eggs being oviposited in Spring and Autumn than in Winter. No such effect was observed with the constant temperatures.

The number of eggs per cluster was 22.5 in Shade-house, 23.2 at 16 °C, 22.9 at 24 °C, and 18.5 at 5 °C. The average number of clusters oviposited per slug was 1.3 in Shade-house, 1.4 at 16 °C, 1.1 at 24 °C and 0.4 at 5 °C. The average number of eggs laid by each slug in this part of the experiment was 28.7 in Shade-house, 31.8 at 16 °C, 25.2 at 24 °C, and 7.7 at 5 °C. The optimal condition for slugs to oviposit was at 16 °C.

Thirteen D. panormitanum and fifteen D. reticulatum that hatched on the same day were kept in the laboratory till natural death ensued. The average number of eggs per cluster for D. panormitanum was 15.6, and for D. reticulatum 15.4 . The number of clusters per slug was 3.8 for D. panormitanum and 3.5 for D. reticulatum, and the average number of eggs oviposited per slug was 59.8 for D. panormitanum, and 53.4 for D. reticulatum.

The effects of Temperature, Humidity, and Evaporation-rate, was correlated with oviposition rate. An increase in temperature and evaporation-rate showed a positive correlation, with an increase in oviposition rate. Humidity has a negative correlation with oviposition rate.

Significantly more eggs hatched from D. panormitanum 59.9 % , than of D. reticulatum 53.0 % , under laboratory conditions.

The time taken for eggs to hatch is temperature dependent, taking for D. panormitanum an average of 33.7 days for Shade-house, 20.9 days at 16 °C, 16.5 days at 24 °C, and 103.4 days at 5 °C. The average number of eggs hatched for D. panormitanum in Shade-house was 38.3 % , at 16 °C 37.0 % , at 24 °C 32.1 % , and at 5 °C 25.4 % .

In the laboratory D. panormitanum's average life-span was 171 days, and D. reticulatum 151 days. At the four temperatures D. panormitanum survived for an average of 32.7 days in Shade-house, 23.2 days at 16°C, 16.8 days at 24 °C, and at 5°C for 63.1 days.

In part 'B' eightythree biocides were tested against the slug species D. panormitanum and D. reticulatum. These included 16 fungicides, 16 insecticides, 26 herbicides, and 2 molluscicides, at the maximum rates as specified by the manufacturer. Five fungicides, two insecticides, five herbicides, one molluscicide, and seven of the combinations showed high ovicidal activity. Five insecticides, one molluscicide, and ten of the combinations showed high toxicity when ingested, and two insecticides, one molluscicide, and six of the combinations were highly effective when used as a surface spray. Metaldehyde and methiocarb were effective in all three treatments, and phorate was a good bait and contact molluscicide. Dazomet caused a reluctance by slugs to cross the treated area to obtain food, and as a result died of starvation in the refuge area.

The effects of all two possible combinations of three herbicides and three insecticides could not be determined from a knowledge of their individual properties. Each reacted in an undetermined manner according to their combined properties.

ACKNOWLEDGEMENTS.

I would like to thank Professor B.P. Springett for the supervision of this Thesis, and Dr. J.A. Springett for the co-supervision, and valuable advice given during the preparation of the Thesis. Thanks is also due to Ivon Watkins Dow for the supply of industrial grade phosphate.

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INTRODUCTION

Aims of study.

Two species of slugs, Deroceras panormitanum (Lessona & Pollonera, 1882), and Deroceras reticulatum (Muller, 1774), were chosen as a subject for research because of a lack of information available for both species as applied to New Zealand conditions. Overseas literature deals primarily with D.reticulatum and Arion species.

The aims of this study are;

- (a) To observe and test if D.reticulatum acts similarly in this country.
- (b) To determine if D.panormitanum acts in a manner similar to D.reticulatum.
- (c) To observe and record the fecundity of D.panormitanum taken from the field, and under laboratory conditions.
- (d) To determine if temperature effects cause changes in egg-laying, hatching rate, and survival of slugs.
- (e) To test commonly used biocides on the two species of slugs (eggs, juveniles, adults), for molluscicidal properties.

SLUG BIOLOGY

Slugs are known common pests of agriculture and horticulture, and may be found in large numbers in damp places. This makes cover crops such as pastures and potatoes especially vulnerable to attack. High losses, both at the seed and early seedling stage, and later by spoiling ripening fruit and vegetables can be attributed to these pests.

Slugs have been classed as major economic pests during the establishment of cereals in temperate climates (Runham and Hunter, 1970; Newell, 1966; Duthiot, 1961.). They are also garden pests feeding on potatoes, lettuce, carrots, chrysanthemums, brassicas, legumes, and young seedlings.

H.J.Gould (1962) in field experiments found D. reticulatum associated with hollowed grain and shoots which had been severely grazed below the soil surface. Control measures are usually taken after braiding when slug damage to the young seedlings become obvious. Therefore much loss of seed may have already occurred below ground.

Slug populations can increase dramatically at the soil surface with overhead irrigation, and Howitt (1961) found that slugs could destroy a field of Ladino white clover in a single season.

In England damage by slugs is evident in late Autumn and early Spring. D. reticulatum is an important pest on farms, and is well adapted to life at low temperatures (Mallanby, 1961). Reasons why damage occurs at this time is that (1) alternative food sources are scarce, and crop plants such as germinating wheat are sometimes the only food available. (2) Slugs are active at temperatures which would put most poikilothermic animals into a chill-coma. (3) Some slug species are naturally most numerous in winter (Barnes, 1948).

Slugs emerge from a hole or refuge, crawl on the surface, feed, copulate if they find a mate, crawl, feed again, and finally, before daybreak, return to the refuge from which they emerged (Newell, 1966). The time spent on each of these nocturnal activities varies within wide limits. This type of behaviour suggests that the majority of slugs remain in a relatively small area, and that pest-control measures aimed at slugs need only be applied to areas of a garden, or crops, covering their home range (Newell, 1966).

Weather has an influence on slugs, but it is difficult to ascertain which aspect has the most influence. Crawford-Sidebotham (1972) found that the activity of slugs is both a function of temperature and the vapour pressure deficit. Slugs have a permeable cuticle and therefore lose body-water continuously in a dry atmosphere. Activity tends to increase with increasing temperature, and decrease with increasing vapour pressure deficit.

Water relations is the most single important factor affecting the activity, reproduction and survival of slugs (Stephenson, 1968). A large daily water loss is usual for slugs, and they can survive for short periods in dry conditions, and remain active enough to move to a more favourable habitat.

In temperature trials on feeding Hunter (1968) found (a) D. reticulatum has a greater tendency to feed on green vegetation than the underground dwelling Arion hortensis Ferussac, 1819, and Milax budapestensis (Hazay, 1881). (b) Feeding activity of all three species increased as the temperature rose to 20°C, but slowed at 25°C. (c) At a low temperature of 5°C, D. reticulatum was found to be the most active of all the three species.

D. reticulatum has two generations per year in the Northern hemisphere, a Spring generation hatching in May, and an Autumn generation hatching in late September. The latter taking seven months per generation, and the former five months (Hunter, 1968).

The oviposition places for slugs are not selected at random. Soil of approximately 75% moisture was found to be the most suitable for the oviposition of eggs by D. reticulatum (Arias and Crowell, 1963).

Carrick (1942) came to a similar conclusion, and stated further that in soils below 10% saturation, or close to 100 % saturation will not allow normal slug development. Some decomposing plant matter in the soil is also essential, as this forms part of young slug's food (Carrick, 1942).

In an experiment on the effect of temperature on egg production, Stephenson (1966) found that the slug Milax budapestensis when kept at fluctuating temperatures of 10 °C to 20 °C laid more eggs than at a constant temperature of 20°C.

Differences in egg production by the slug D. reticulatum was noticed by Hunter (1968) from slugs collected from the field shortly before the breeding season. These slugs laid an average of 24 eggs per individual and died soon afterwards. Slugs kept in cultures from their young stages, laid an average of 32.5 eggs per individual.

The total number of eggs laid differ from species to species, and more eggs are laid in laboratory cultures than in the field (Carrick, 1938). Egg numbers laid by laboratory slugs were ; Limax maximus Linnaeus, 1758, 676-874 eggs per slug; Limax marginata (Muller, 1774), 105-132 eggs per slug; Arion hortensis, 150 to 203 eggs per slug, and for D. reticulatum up to 300 eggs per slug (Stephenson, 1968). Hunter (1968) found eggs of D. reticulatum in soil samples at all times of the year, and numbers

fluctuated widely - fewer in Summer, and peaks in Autumn and Spring. Most species of slugs do not lay all their eggs at one time, and Stephenson (1968) found that 2-3 clusters were oviposited containing from 4-400 eggs depending on the species. However the usual variation per cluster is from 10-15 eggs to 40-50 eggs per cluster (Stephenson, 1968).

Temperature affects the time taken for eggs to hatch, and there are also some species differences. Hunter (1968) in temperature experiments on eggs of Arion hortensis found that the time taken for eggs to hatch at 20 °C was two weeks, at 15 °C three weeks, at 10 °C four to five weeks, and at 5 °C fourteen weeks. The incubation period for D. reticulatum eggs has been reported to range from 15-65 days (Taylor, et. al., 1907). Arias and Crowell (1963) found that at 20 °C the period of incubation for D. reticulatum eggs was between 11 to 21 days with a mean of 15.5 days, and at 5 °C eggs took 105 days to hatch.

Most workers have to depend on field collected slugs for their test animals, which are usually abundant only in the Spring and Autumn (Arias and Crowell, 1963). In slug cultures, many of the slugs brought in from the field die as a result of diseases contracted while in the field. At least forty-six species of invertebrates are known to be associated with twenty-five species and subspecies of slugs (Stephenson and Knutson, 1966). Ten species of invertebrates are known to kill 14 species of slugs, and the frequency with which infested and damaged slugs are found in nature, suggests that biological control may be possible. The protozoans, brachylaemid flatworms, lungworms, lampyrid beetles, and some sciomyzid larvae seem to be the most important natural slug enemies (Stephenson, 1968). Carabids are known to prey on slugs, and when Judge and Kuhr (1972) caged two of these animals with seven to fourteen-day old D. reticulatum in the laboratory, one hundred slugs were consumed in three days.

CHEMICAL CONTROL OF SLUGS

Early attempts to kill slugs included nocturnal dressings of fields with copper-sulphate (Anderson and Taylor, 1926), and the use of paris-green and bran baits (Miles et.al., 1931). Meta (metaldehyde) was first mentioned as a slug bait by Haddon (1936), who recommended its use mixed with bran. Further references followed quickly in scientific and horticultural literature. Metaldehyde in bran baits (Gimingham and Newton, 1937), gave a better kill and remained the standard treatment for many years. Metaldehyde is most effective when dry conditions follow its application, because many slugs who ingest a sublethal dose are killed by dehydration.

To be effective baits must be attractive and toxic, and must be able to withstand variable climatic conditions. They must also be adaptable to conventional methods of application, and be economical. To reach their site(s) of action, molluscicides must be inhaled, ingested, or absorbed over the body surface (Judge and Kuhr, 1972). A constant flow of slime which is a characteristic of slugs, poses a special problem as it is possible that lipid-soluble insecticides will not readily pass through this water-based barrier (Judge and Kuhr, 1972). Systemic insecticides are water-soluble and would therefore be more likely to penetrate the slime. Webley (1962) found that different species of slugs react in varying ways to certain molluscicides.

Trials with various molluscicides have been carried out before and since the discovery of metaldehyde. Some chemicals are claimed to have better molluscicidal properties, and others claim better toxicity when additives are combined with metaldehyde. The following is an incomplete list of Authors and their findings.

Goold (1962) experimented with six chemical sprays, two chemical powders,

and two slug baits, on a wheat plot. None of the chemicals gave better results than the standard metaldehyde bran baits. Metaldehyde and D.N.O.C. gave some promise as a spray, and copper-sulphate as a powder. The other chemicals tested were; (1) as sprays, pentachlorophenol, sodium arsenate, and copper-sulphate. (2) as a powder, calcium cyanamide, and as a bait, paris-green with bran.

A.J. Howitt, (1961) in his experiments on slugs found metaldehyde applied at a rate of 1-2 lb a.i./acre, as a suspension into the irrigation system was sufficient to reduce the slug population, and increase Ladino white clover production.

B.D. Barry (1969) found that phorate (E.C.) at a rate of 1-1.5 lb a.i./acre, was the only economical chemical tested that produced appreciable reductions in slug populations. Metaldehyde meal applied at a rate of 2 lb a.i./acre was also effective in reducing slug populations, but he found this rate to be non-economic.

I.F. Henderson (1969) administered biocides to slugs by forced ingestion. This method did not measure the attraction or repellent effects of the materials tested on the slug D. reticulatum. The median lethal doses for the three biocides were;

(1) Sodium pentachlorophenate	22.9 ± 2.5 ug / slug	= most toxic.
(2) Metaldehyde	85.2 ± 4.0 ug / slug	
(3) Copper-sulphate	129.0 ± 5.9 ug / slug	

Judge and Kuhr (1972) tested 29 chemicals for molluscicidal properties. Of these eight showed some potential. Two were the molluscicides metaldehyde and carbaryl, and the other six were the insecticides; phorate, zinophos, methomyl, aldecarb, du-Pont 1410, and du-Pont 1764. Metaldehyde was found to be the most toxic. The carbamates and phosphates were also highly toxic, and their mode of action on animals is by

inhibiting cholinesterase, which causes a disruption of nervous activity, and eventual death (O'Brien, 1967). Presumably their action is similar on slugs.

Musick (1972) applied phorate at a rate of 1 lb a.i./ acre as a broadcast spray to the soil surface against the slug D. reticulatum. With one application there was a significant reduction in the slug population, but with a properly timed second application maximum population reduction was achieved.

Symonds (1975) stated that metaldehyde was a more effective treatment against slugs than methiocarb when field conditions were favourable to its action. Methiocarb however gave more consistent results under a wide range of field conditions.

Charlton (1978) showed that legume seed coated with methiocarb had a higher survival rate at six weeks after sowing than untreated seeds, in box experiments. A field trial showed little benefit from commercial seed coating, with and without methiocarb.

H.H. Crowell (1977) tested the effects of seventy chemicals on slugs. As a result of these tests a series of dinitro-alkyl-phenols were shown to be as toxic by contact as metaldehyde against D. reticulatum. Also several of the dinitro-phenol compounds were found to be ovicidal at low concentrations.

Godan (1966) found some differences in susceptibility to molluscicides between juveniles and mature slugs. He also found species differences to molluscicides, some showing higher mortality and others a lower mortality.

SLUGS IN NEW ZEALAND

In New Zealand the four most widely distributed pest species of slugs are; Arion hortensis, D.panormitanum, D.reticulatum, and Milax gagates (Draparnaud, 1801), (Barker, 1978).

In this study the two most common species found in pastures and orchard were D.panormitanum and D.reticulatum, and these were used in this investigation (Appendix I). These slugs were plentiful for most of the year, but showed a decline in numbers when the weather became warm and dry.